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# Sensitivity of Shallow Water Transmission Loss to Source And Receiver Proximity to a Hard Bottom Under Downward Refracting Conditions

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Under downward refracting conditions, raypaths from a shallow source will tend to have grazing angles at a hard bottom that are greater than the critical angle and, therefore, suffer a relatively large loss per bounce. As the source depth increases, lower grazing angles can be obtained. When the grazing angle becomes less than the critical angle, bottom loss per bounce is significantly reduced, allowing a possible reduction in propagation loss. analysis is made for a North Atlantic shallow water area south of Long Island under summer conditions to determine the sensivity of transmission loss to changes in source and receiver depth for ranges up to 50 km. The results are compared to the previous results of Cole and Podeszwa [B. F. Cole and E. M. Podeszwa, J. Acoust. Soc. Am. 41, 1479-1484 (1967)].

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# SENSITIVITY OF SHALLOW WATER TRANSMISSION LOSS TO SOURCE AND RECEIVER PROXIMITY TO A HARD BOTTOM UNDER DOWNWARD REFRACTING CONDITIONS

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**Viewgraph 1**

## 1.  INTRODUCTION

One of the present Navy standard shallow water propagation prediction models gives results that are independent of source/receiver depth (Reference 1). We would like to improve on this assumption with the goal of minimizing propagation loss in shallow water by optimum source/receiver placement, especially under strongly downward refracting (summer) conditions. We present in this paper our first results on the sensitivity of source/receiver placement over a hard (Biot type) bottom in shallow water under downward refracting conditions.

## SHALLOW WATER LOCATIONS
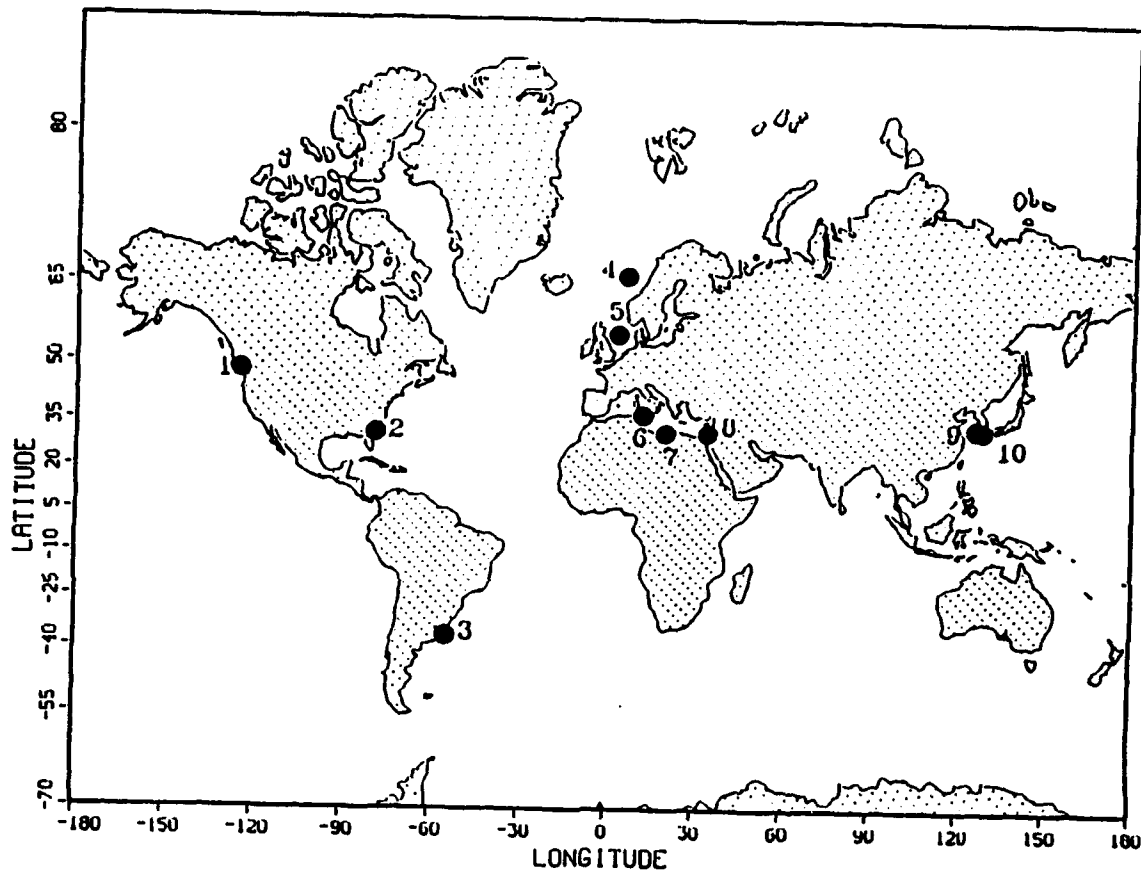
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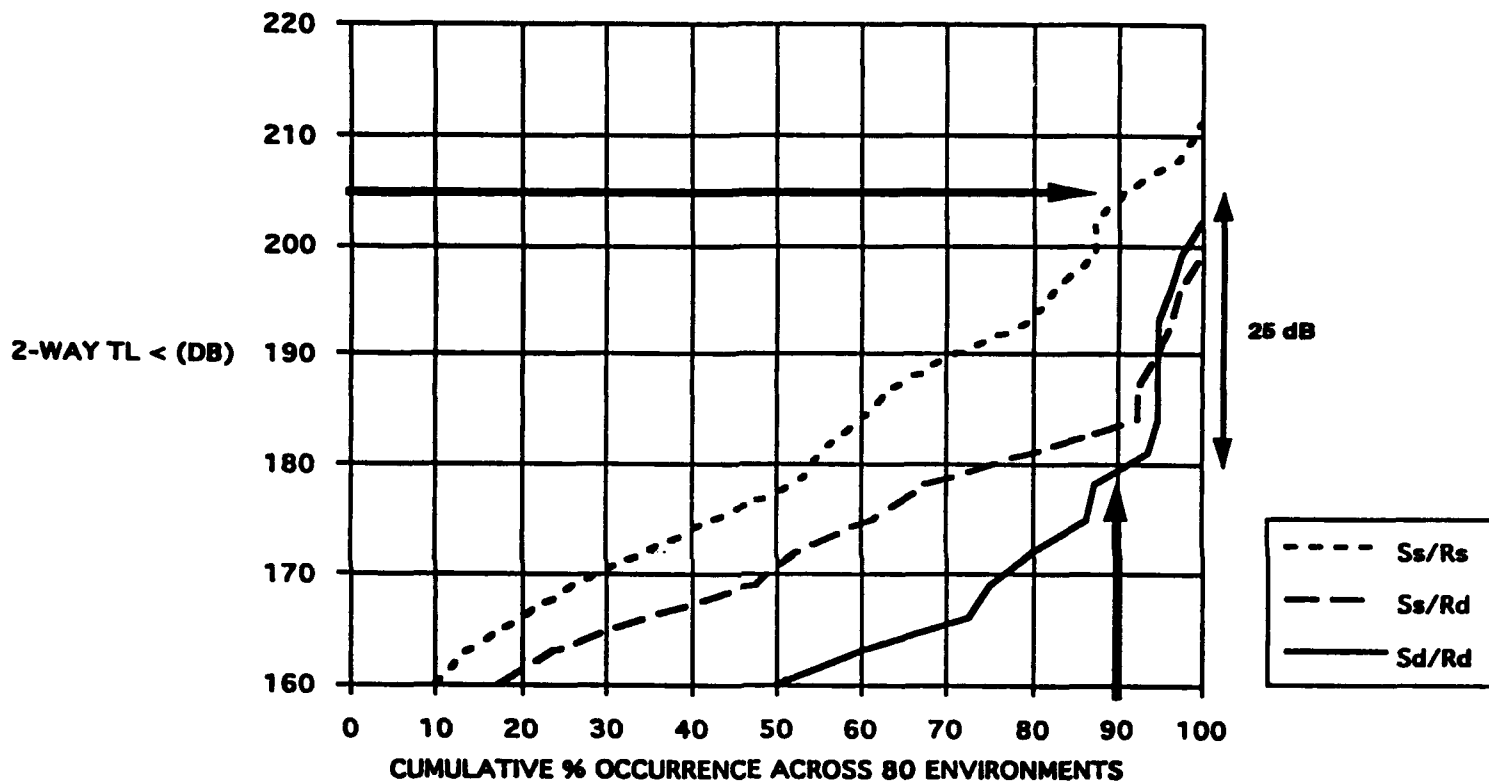**Viewgraph 2.  Map**

## 2.  PREVIOUS RESULTS

This work is a follow-on to two previous studies.  The first was a recent general study of year-round sound propagation conditions (500 - 5000 Hz) at 10 locations throughout the world, which we reported at a previous meeting of the Acoustical Society (Reference 2).  Of the 10 sites studied, seven were found to have a "hard," or low-loss bottom.

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TWO WAY TRANSMISSION LOSS
FREQUENCY =500 Hz
RANGE =10 nmi
TARGET DEPTH = DEEP

**Viewgraph 3.  Summary Two-Way Transmission Loss**

The cumulative percent occurrence for a given two-way transmission loss for 80 different scenarios (10 locations, 4 seasons for each) shows that, for most situations, there is significantly less loss for a "deep" source and receiver configuration.  "Deep" is taken generically to mean off the bottom but below the base of the thermocline.  This was found to be especially true under strongly downward refracting conditions.  This result led us back to the historical studies of Cole and Podeszwa (Reference 3).

**THEORETICAL CURVES
OF PROPAGATION LOSS
VS RECEIVER DEPTH
(SHALLOW SOURCES)**
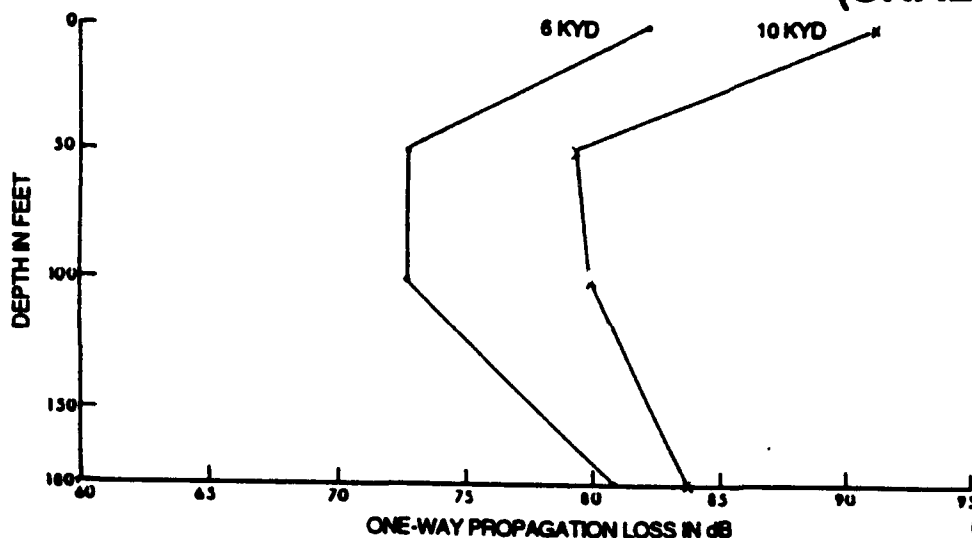
**Viewgraph 4. Propagation Loss from Cole and Podeszwa**

Cole and Podeszwa showed that, for a shallow water region with a "hard" bottom, propagation loss was not independent of source and receiver depth and that, for a shallow source under downward refracting conditions, there would be an optimum receiver depth.

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## SHALLOW WATER SOUND SPEED PROFILE
## (SOUTH OF LONG ISLAND, MAY)
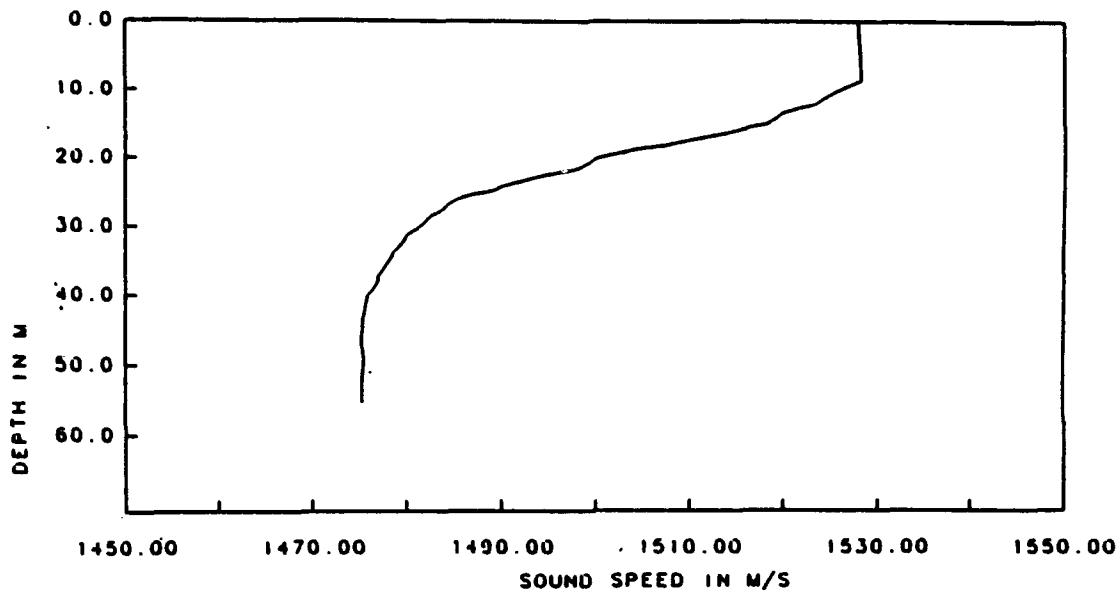
**Viewgraph 5.  Sound Speed Profile Area Foxtrot**

## 3.  ENVIRONMENTAL CONDITIONS AT AREA FOXTROT (SUMMER)

We chose to study the sensitivity of transmission loss to source and receiver depth at the same area Foxtrot -- a shallow water region on the New England shelf south of Long Island -- under downward refracting (summer) conditions. The sound speed profile showed a weak shallow surface duct followed by a strong negative gradient. The water depth was approximately 57 meters.

# THE MINIMUM OBTAINABLE BOTTOM GRAZING ANGLE IS A FUNCTION OF SOURCE DEPTH

$$\Theta \min = \cos^{-1} \frac{C_{SOURCE}}{C_{BOUNDARY}}$$

SOURCE

DEPTH

$\Theta$ min

RANGE

DEPTH

SOURCE

$\Theta$ min

RANGE

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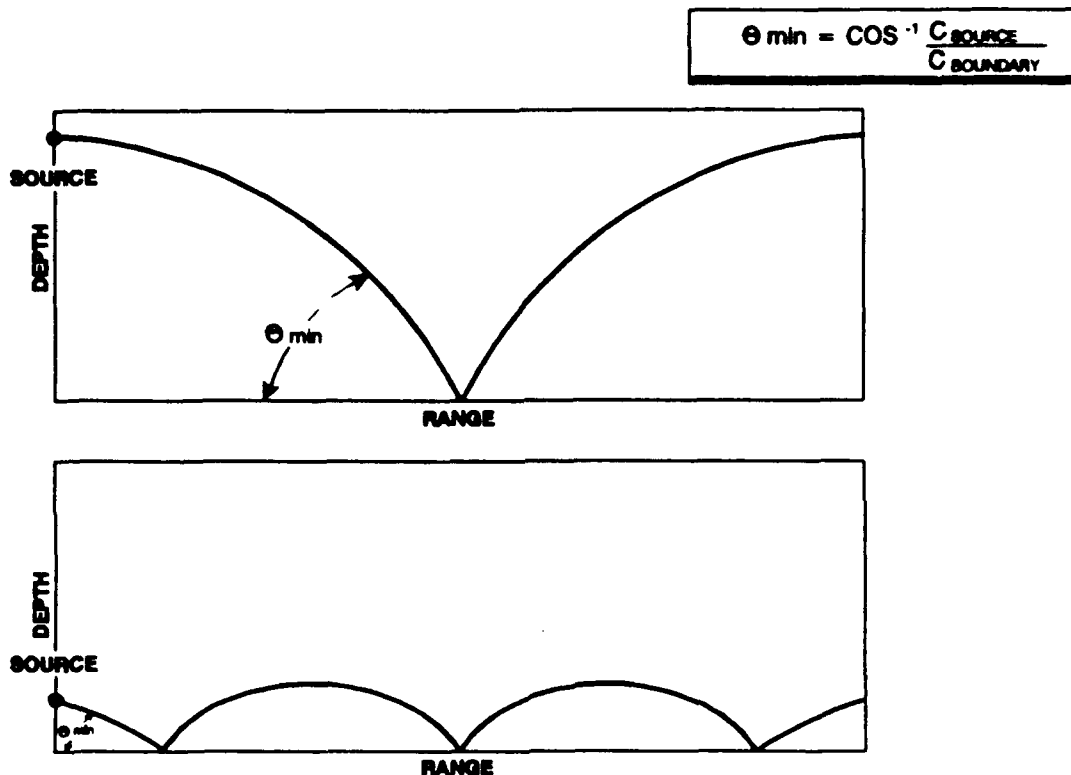
**Viewgraph 6.  Minimum Obtainable Bottom Grazing Angle**

The minimum grazing angle can be expressed simply as the inverse cosine of c(source)/c(boundary). With a downward refracting sound speed profile, generally the shallower the source, the greater the ratio of c(source)/c(boundary) and, hence, the greater the minimum grazing angle. Typically, for a near surface (10 meters) source/receiver, the minimum grazing angle was 15 degrees; for a source/receiver "deep" (50 meters), it was 5 degrees.

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# BIOT THEORY

**BOTTOM LOSS FOR MEDIUM SAND**
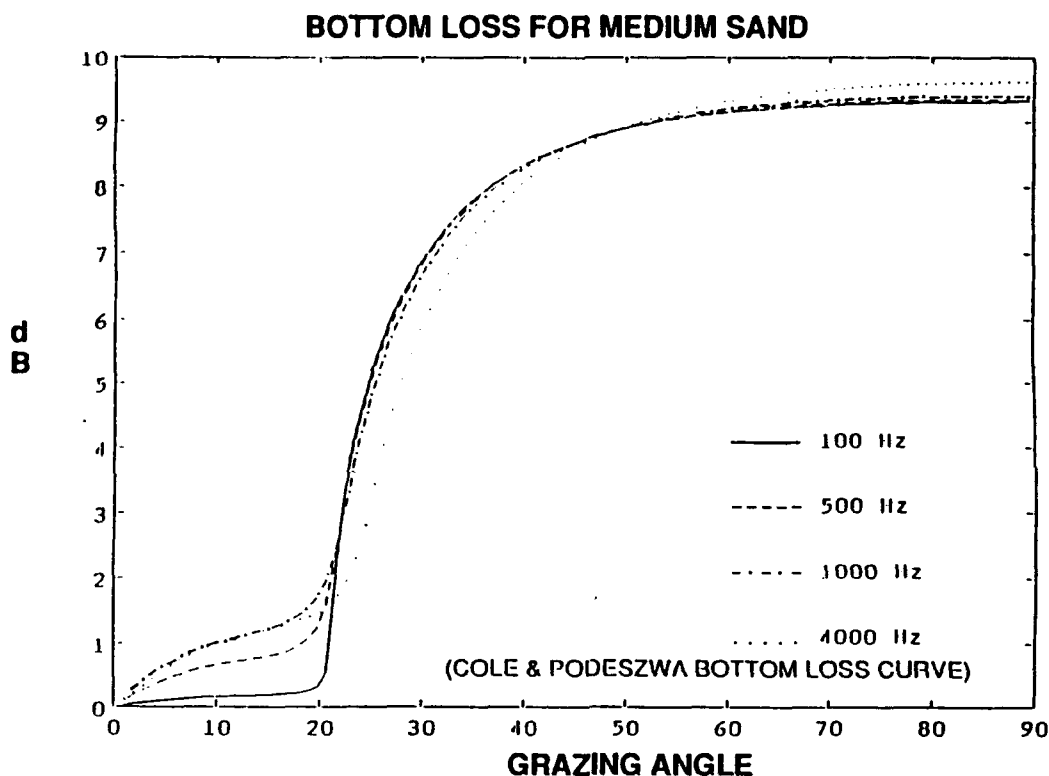


**Viewgraph 7. Biot Bottom Loss Curve**

Chizhic and Tattersall (Reference 4) have developed bottom loss vs grazing angle curves for various frequencies for area Foxtrot based on Biot theory (assuming medium sand). Their results were in excellent agreement with the experimental measurements of Cole (Reference 3). These results show the strong grazing angle dependence of bottom loss and suggest that, since bottom loss is the dominant factor in low frequency propagation loss under downward refracting conditions, considerable improvement could be obtained if the grazing angle was reduced. This could be done, for example, by shifting a near surface (10 meter depth) source/receiver down to a "deep" depth (for Foxtrot, this would be 50 meters).

# SHALLOW WATER TRANSMISSION LOSS

## FREQUENCY 800 Hz                    BOTTOM TYPE ZERO LOSS

SOURCE DEPTH 10.0, 50.0 -

RECEIVER DEPTH 10.0, 50.0
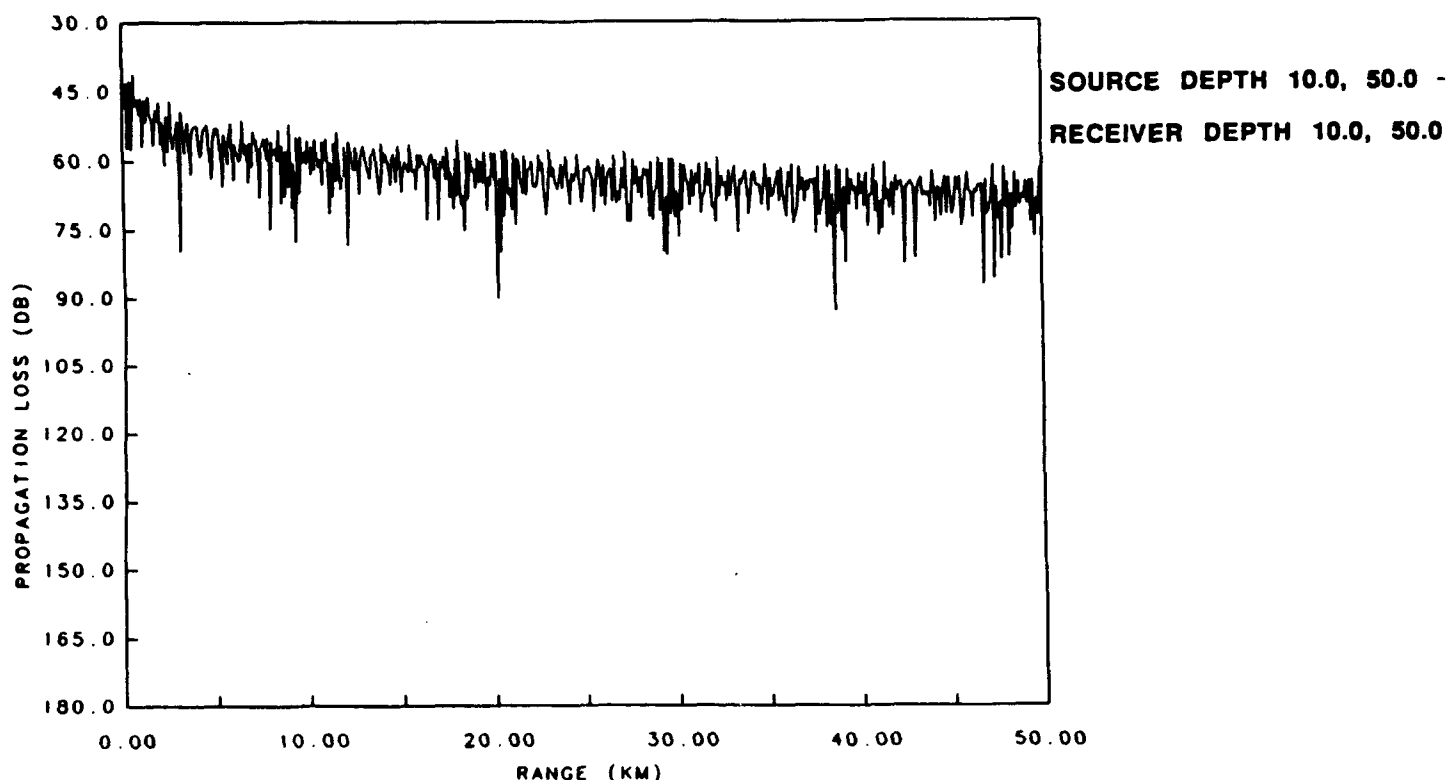


**Viewgraph 8.   Shallow Water Transmission Loss:   Zero Bottom Loss**

## 4.  DEPTH DEPENDENCE OF TRANSMISSION LOSS

To verify this assumption of reducing transmission loss by shifting source/receiver depth, propagation loss was computed using the Kanabis normal mode model (References 5, 6) at a frequency of 800 Hz, the sound speed profile shown in figure 4, and a flat bottom depth of 57 meters.  We chose to compare a source/receiver depth of 10 meters with a source/receiver depth of 50 meters.  Our first result was a "calibration" -- by assuming no bottom loss, we should get the obvious answer that both depth configurations would have the same propagation loss.  This is, indeed, the modeling result we got.

# SHALLOW WATER TRANSMISSION LOSS

**FREQUENCY 800 Hz**          **BOTTOM TYPE 1.3 dB LOSS**



SOURCE DEPTH 50.0
RECEIVER DEPTH 50.0
SOURCE DEPTH 10.0
RECEIVER DEPTH 10.0
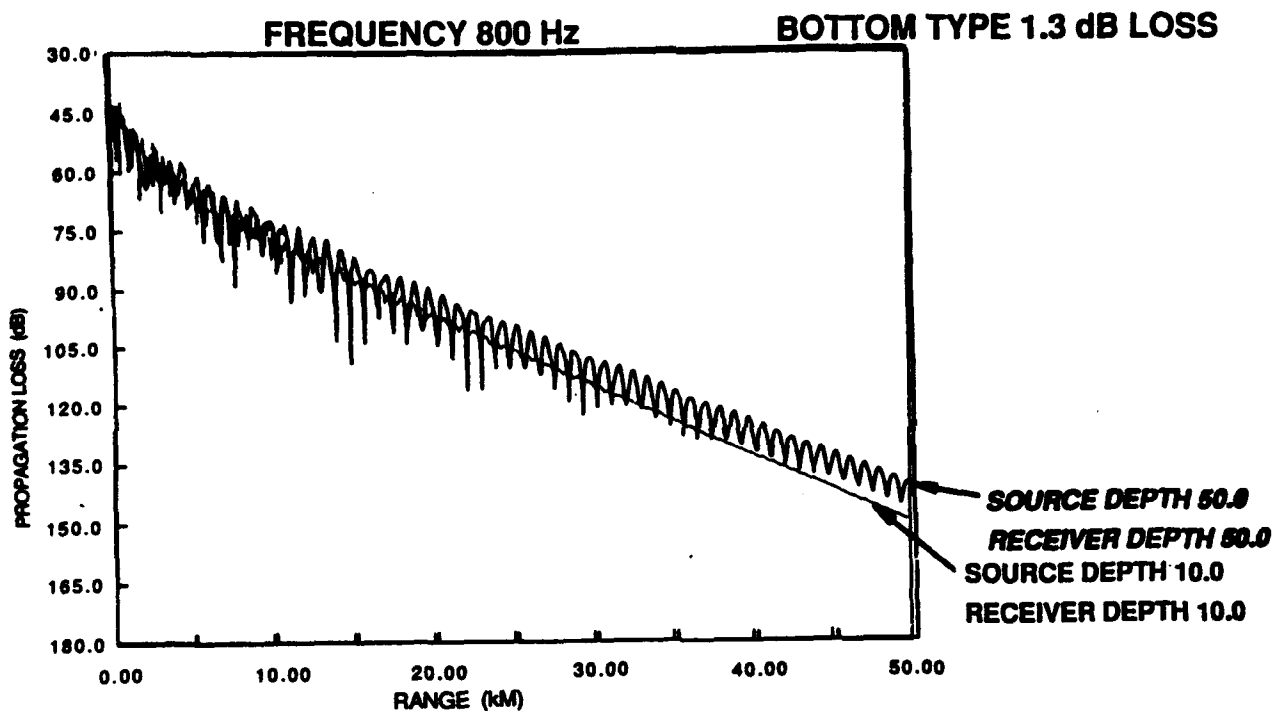
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**Viewgraph 9.  Shallow Water Transmission Loss:  1.3 dB Loss Per Bounce**

We next repeated the computations, assuming a 1.3 dB rather than a 0 dB per bounce loss for all angles.  This result  would obviously not be sensitive to the grazing angle bottom loss dependency, but it would show if there is a significant grazing angle dependency to the number of bounces in shallow water.  This would result in a change in transmission loss due to a change in the total propagation path length.  For example, would the steeper grazing angle (approximately 15 degrees) from the 10 meter source/receiver result in a significantly different  number of bounces, and hence transmission loss, than the lower angle (approximately 5 degrees) for the 50 meter source/receiver.  The results indicate that there is not a significant difference in the number of bounces.

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# SHALLOW WATER TRANSMISSION LOSS

### FREQUENCY 800 Hz　　　　　BOTTOM TYPE BIOT (SAND)



*SOURCE DEPTH 50.0*
*RECEIVER DEPTH 50.0*

SOURCE DEPTH 10.0
RECEIVER DEPTH 10.0
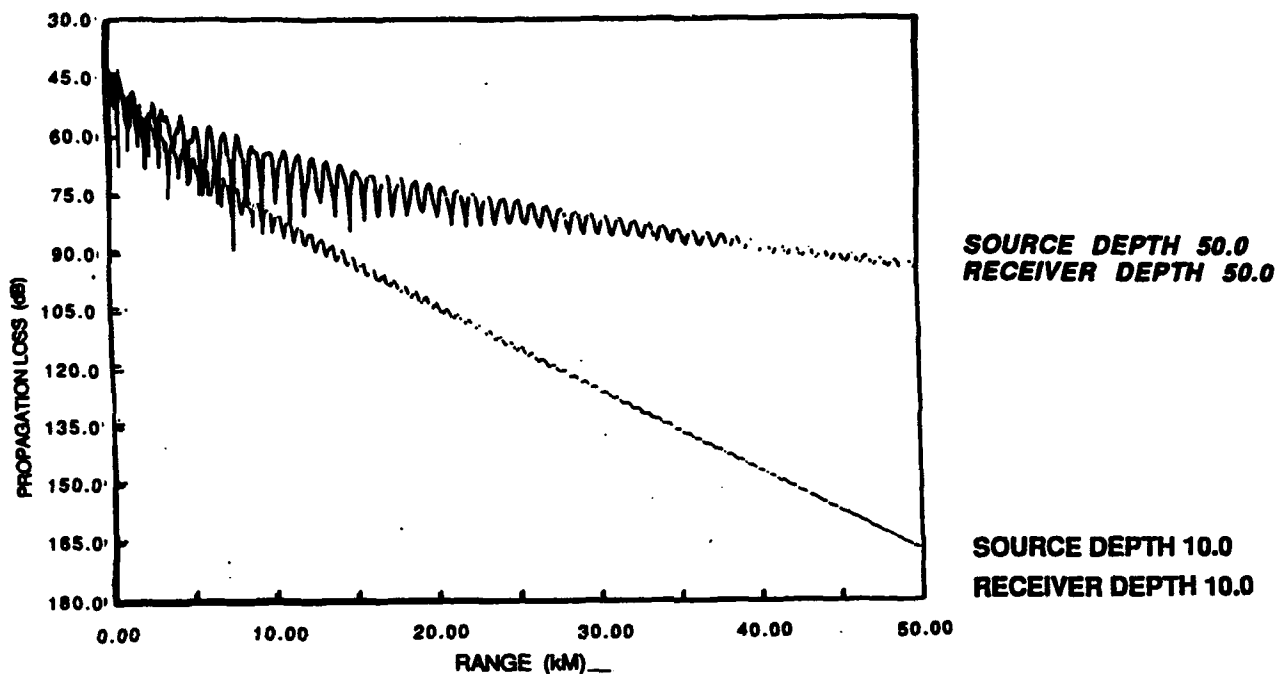
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**Viewgraph 10.   Shallow Water Transmission Loss: Biot Bottom Loss**

We now repeat the transmission loss computations with the grazing angle dependent Biot bottom loss. The results show a significant depth dependence. The lower grazing angle associated with the 50 meter source/receiver results in a lower bottom loss and, correspondingly, a lower transmission loss than the 10 meter source /receiver and its 15 degree grazing angle.

# PHENOMENOLOGICAL EXPLANATION OF DEPTH DEPENDENT TRANSMISSION LOSS

**BOTTOM GRAZING ANGLE vs S/R DEPTH**

**MINIMUM BOTTOM LOSS vs S/R DEPTH**
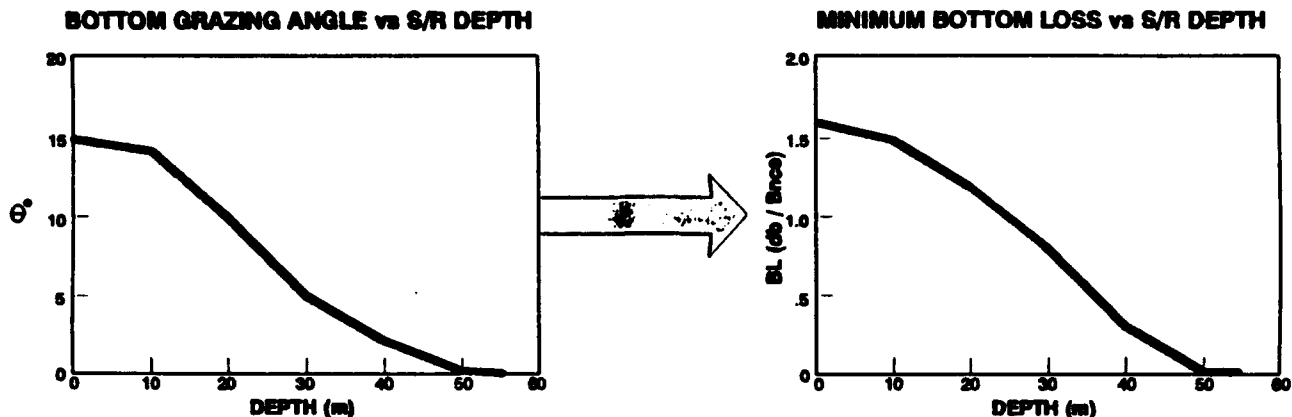


S/R DEPTH = min [SOURCE DEPTH, RECEIVER DEPTH]

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**Viewgraph 11.  Phenomenological Explanation of Depth Dependency**

## 5.  EXPLANATION OF RESULTS

The source/receiver depth dependency of transmission loss can be phenomenologically explained by these diagrams.  For a shallow water, downward refracting (negative gradient), sound speed profile, the grazing angle vs depth dependency is shown by the diagram on the left.

For a bottom with a grazing angle dependent bottom loss, this can be simply translated into a loss vs source/receiver depth diagram, as on the right.

The plots shown are for the specific case of a summer downward refracting profile at site Foxtrot and a Biot bottom loss model assuming sandy sediment.

They show that , for this case, the bottom loss per bounce for a receiver/source at 10 meters depth will be significantly greater than for a source/receiver at a 50 meter depth and, hence, will result in a greater transmission loss.

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## 6. CONCLUSIONS

1. As Cole and others have previously shown, the exact value of bottom loss, being the dominant loss mechanism, is crucial in determining transmission loss under downward refracting conditions in shallow water.

2. Our example, with a sandy bottom, demonstrates that it is possible to select a source/receiver that will minimize transmission loss even under strongly downward refracting conditions in shallow water.

3. The phenomenological explanation for this result is that, since Biot theory predicts for a sandy sediment, bottom loss will be dependent on the grazing angle, and, under strongly downward refracting conditions in shallow water, the grazing angle at the bottom depends on the source/receiver depth in the water column, it is, therefore, possible to optimally select the source/receiver depth to minimize the propagation loss.

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